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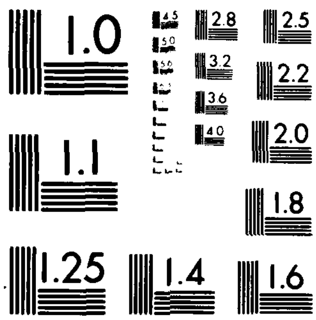

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Sarah E. Goldin and Barbara Hayes-Roth

June 1980

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Prepared For

The Office of Naval Research

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This Note reports an initial investigation of individual differences in planning. Studying how individuals differ in their approach to planning may help us to understand the cognitive activity that underlies the development of a good plan and the factors that limit planning effectiveness, as well as producing prescriptive guidelines for improving planning. The research focuses on the analysis of thinking-aloud protocols produced by five subjects as they performed a set of errand planning tasks, and establishes patterns of individual differences in decision category usage that correlate with planning skill. Effective planners plan at a higher level of abstraction, possess a larger repertoire of planning knowledge and exhibit a greater degree of conscious control of their planning processes. Good and poor planners make essentially the same types of planning decisions, but good planners are more aware of tradeoffs between evaluation criteria. This research should interest cognitive scientists as well as practitioners concerned with improving planning.

PREFACE

This Note describes an analysis of "think-aloud" protocols generated by five subjects as they performed an errand-planning task. The opportunistic planning model developed by Hayes-Roth and Hayes-Roth (1979) provided a conceptual framework for the analysis. The model specifies a number of decision categories that could be matched to subjects' descriptions of decisions made during the development of a plan. The analysis establishes patterns of individual differences in decision category usage that correlate with planning skill. Thus, the Note should be of interest to cognitive scientists concerned with basic planning processes as well as to practitioners concerned with improving planning in real-world domains.

A second Note describing an experimental study of individual differences in planning is projected as a sequel.

This research was supported by the office of the Director of Personnel and Training Research Programs, Psychological Sciences Division, Office of Naval Research, as part of an ongoing Rand project on cognitive processing in planning and control.

SUMMARY

This Note reports an initial investigation of individual differences in planning. Studying how individuals differ in their approach to planning may help us to understand the cognitive activity that underlies the development of a good plan and the factors that limit planning effectiveness. In addition, such a study may produce prescriptive guidelines for improving planning, drawing attention to specific procedures that can be trained or knowledge that can be taught to people who want to learn how to plan more effectively.

The research reported here focuses on the analysis of thinking-aloud protocols produced by five subjects as they performed a set of errand-planning tasks. The protocols were coded into content categories suggested by the opportunistic planning model developed by Hayes-Roth and Hayes-Roth (1979). Final plans were evaluated against a set of normative criteria, such as route efficiency and temporal realism. Then the occurrence of various content categories in the protocols was related to individual subjects' planning scores in an effort to describe patterns of category usage that correlated with planning skill.

This analysis highlighted a number of differences between good and poor planners. Good planners used the available set of decision categories more extensively than poor planners. In particular, good planners made more decisions establishing criteria for plan generation and evaluation, more decisions controlling allocation of cognitive resources during planning, and more decisions assessing data relevant to planned actions. Good planners also made more decisions at higher levels of abstraction, especially decisions concerning the intended

outcomes of the plan and decisions concerning an overall temporal-spatial design for the plan.

Good planners also differed from poor planners in the detailed content of their decisions. They more frequently reviewed and evaluated previous decisions. They were more likely to compare alternative plan actions. They were more sensitive to constraints on when certain errands could be done and to the existence of spatial clusters of errands. They had larger repertoires of decision types governing general plan characteristics. They generated a greater number and variety of decisions determining the focus of attention. Finally, although good planners and poor planners used essentially the same criteria for generating and evaluating their plans, good planners used most of these criteria more frequently than did poor planners.

ACKNOWLEDGMENTS

We wish to thank Cathleen Stasz and Frederick Hayes-Roth for consultation on the research. We thank Perry Thorndyke for his instructive comments on an earlier draft of this Note.

CONTENTS

I. INDIVIDUAL DIFFERENCES IN PLANNING: AN INTRODUCTION

Almost every cognitive task of appreciable complexity includes planning as a component process. Mundane activities, such as a shopping trip or a vacation, as well as specialized tasks, such as computer programming or air traffic control, benefit from effective planning. Thus, an understanding of the cognitive processes involved in planning would have practical as well as theoretical significance.

This Note reports an initial investigation of individual differences in planning. There are at least two reasons for studying how individuals differ in their approach to planning. First, comparing good and poor planners may help us to understand the determinants of effective planning: what cognitive activity underlies the development of a good plan and what factors limit planning effectiveness. Second, such an investigation may produce prescriptive guidelines for improving planning. We may be able to isolate specific procedures that can be trained or knowledge that can be taught to people who want to learn how to plan more effectively.

Although very few studies have investigated skill differences in planning *per se*, numerous studies have focused on individual differences in problem-solving. Newell and Simon (1972) pioneered these efforts with their detailed analyses of individual subjects' behavior in cryptarithmetic, logic, and chess. Although their work emphasized the commonalities across individuals, they also documented considerable between-subject variability. A number of researchers have related individual differences in problem-solving skills to differences in the amount and organization of problem-relevant knowledge (Charness, 1979;

Chase & Chi, 1979; Chase & Simon, 1973(a,b); Chi, Feltovich & Glaser, 1979; Chiesi, Spilich & Voss, 1979; Egan & Schwartz, 1979; Reitman, 1976; Reitman et al., 1979, Voss & Tyler, 1979). Across domains that range from chess and Go to baseball and computer programming, this research has found that problem-solving experts excel at encoding and remembering domain-relevant information because they possess an extensive domain-specific knowledge base. Furthermore, this domain knowledge is organized into functional units that are particularly meaningful and useful for the problem at hand.

Other researchers have found that the problem approach or strategies of experts differ from those of novices. In the domain of physics problem-solving, Larkin (1979; Larkin et al., in press) demonstrated that experts apply physics principles in a different order than do novices, while Simon and Simon (1978) found that experts tend to work forward from problem "givens", while novices work backward from goals. Using a map-learning task, Thorndyke and Stasz (1980) catalogued a number of procedures for focusing attention and encoding map information that distinguished good from poor map learners. Furthermore, they demonstrated that these procedures could be learned, resulting in improved performance.

The present research follows directly in the path of these earlier studies. Our goal was to identify features of the planning process that distinguish good planners from poor planners. Our experimental task required subjects to schedule and plot a route for a day's errands. Subjects were given a scenario that included a list of requested errands, starting and ending locations and times, and, in some cases, other temporal and spatial constraints. In addition, they received a map representing a fictional town, with all routes and errand sites clearly marked. (A sample scenario and the map are included as Figures 1 and 2.) Subjects were instructed to generate a plan for the day that included (a) the errands they planned to accomplish, (b) the order in which they planned to do these errands, and (c) the exact routes they planned to take between successive errands. We reasoned that performance on this everyday task should not be influenced by differences in experience or domain-specific knowledge, and thus should reflect uncontaminated variation in the cognitive processes underlying planning.

Like many of the studies cited above, our effort to uncover individual differences in planning focused on thinking-aloud protocols. The opportunistic planning model of Hayes-Roth and Hayes-Roth (1979) provided a framework for our formulation of hypotheses and analysis of protocols. The next section of this Note provides an overview of this model and outlines its implications regarding possible loci for individual differences. Following this theoretical overview, the third section describes our method: the experimental task, plan evaluation methods, and protocol analysis procedures. The fourth section presents and discusses analyses of planning protocols from five subjects on six different planning problems. The final section summarizes our conclusions.

Scenario 1

This afternoon you're giving a birthday party for Johnny, your 10-year old son. You have to get things for the party and a present, plus you have other errands which you didn't have time to do yesterday. You have to buy ice cream at the ice cream store and pick up the birthday cake at the bakery. You need party decorations which you can pick up at either department store. Your son wants a baseball bat and glove for his birthday and you can get the one he wants at the sports equipment store. In addition to the party items, you didn't get to the post office yesterday to pick up an insured package which may be a birthday present. You need some heavy duty hooks for hanging plants at the hardware, and you need to buy a few items at the drug store. The steam kettle you just bought at Truc has a defective enamel coating and you need to exchange it. Some papers are waiting for your signature at your lawyer's office. You missed your dance class last week and you can take a makeup class at either 10:30 or 11:30. The dance class lasts one hour.

It's quite a full day's schedule. You can plan the day any way you like and do the errands in any order you choose. It is now 9:30 and you have to be back to the car by 1:00 so you can get home in time to decorate the house and set up the games before the kids arrive.

You just filled up the tank at the Oak Street gas station, and you need to park in one of the garages and then go by foot to do the errands. It takes 15 minutes to cross town by foot in either direction. You probably won't be able to do everything, but do the best you can.

Errand List

Oak Street gas station 46
buy ice cream 64
buy birthday cake 16
buy decorations at either department store 57, 77
buy baseball hat & glove at sports equipment store 29
pick up package at post office 23
buy hooks at hardware store 95
buy items at pharmacy 6, 63
exchange tea kettle at Truc 66
sign papers at lawyer's office 62
take dance class 3

Fig. 1

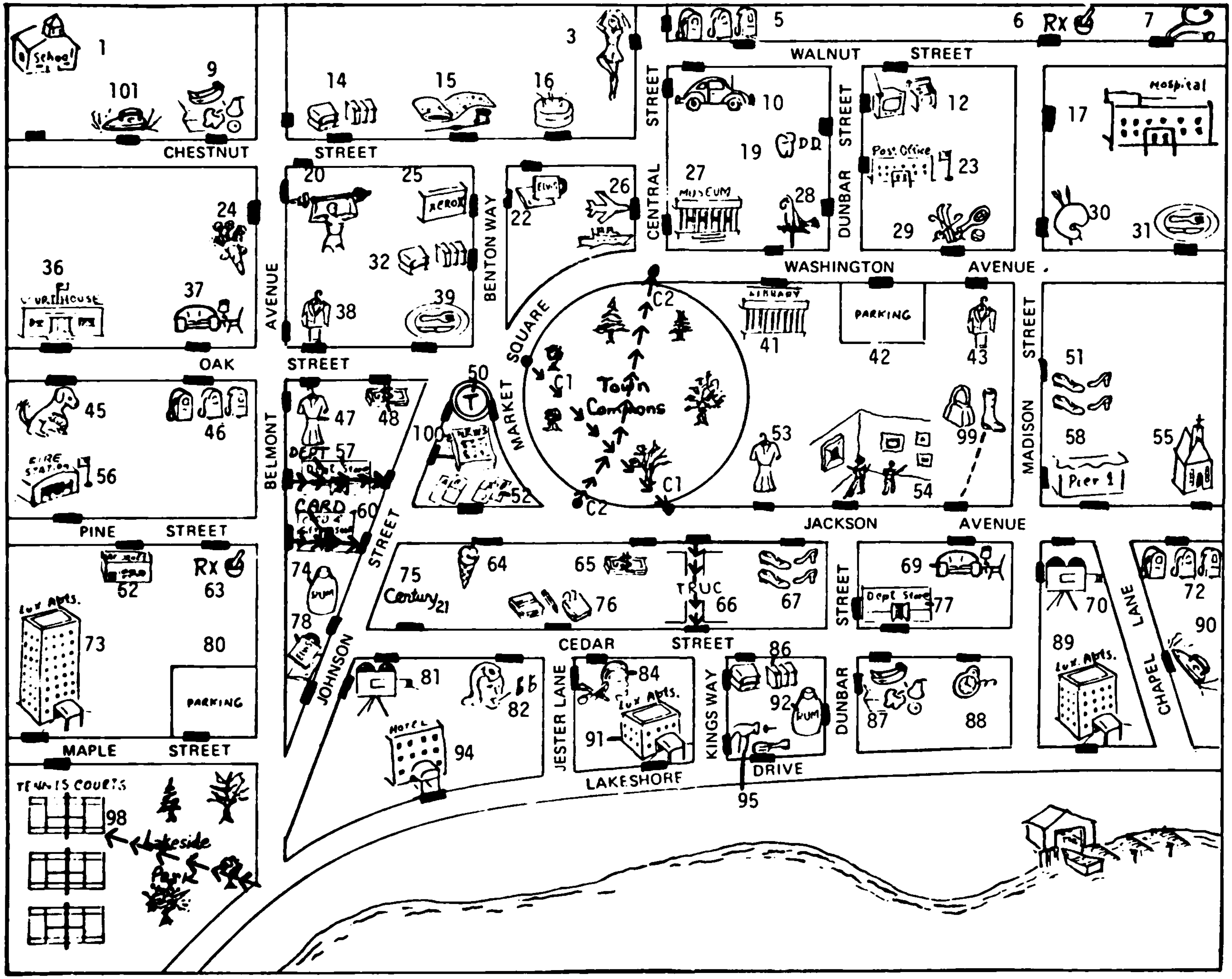
WALNUT STREET
CHESTNUT STREET
CENTRAL STREET
DUNBAR STREET
WASHINGTON AVENUE
AVENUE
OAK STREET
BENTON WAY
SQUARE
MARKET
BELMONT
PINE STREET
MAPLE STREET
JOHNSON STREET
MADISON STREET
JACKSON AVENUE
CEDAR STREET
JESTER LANE
KINGS WAY
LAKESHORE DRIVE
CHAPEL LANE
School
Hospital
Post Office
MUSEUM
LIBRARY
PARKING
Town Commons
Pier 1
Court House
FIRE STATION
DEPT STORE
CARD
Century 21
TRUC
Dept Store
LUX APTS.
HOTEL
TENNIS COURTS
Lakeside Park

Fig. 2--Map

II. THE OPPORTUNISTIC PLANNING MODEL

The opportunistic planning model (OPM) views planning as the cooperative effort of many independent "plan specialists." Each specialist makes tentative decisions for incorporation into the developing plan. Different specialists possess different types of planning knowledge and hence influence different aspects of the plan. For example, some specialists suggest high-level, abstract additions to the plan, while others suggest detailed sequences of specific actions.

Specialists record their decisions in a common data structure, the "blackboard." Each specialist can examine prior decisions posted on the blackboard, transform or combine that information with its own knowledge, and generate new decisions. The blackboard is partitioned into several "planes" corresponding to different conceptual categories of decisions. Each plane is further partitioned into several "levels of abstraction." The blackboard structure restricts the amount of information each specialist must consider in order to generate a decision. It also provides a conceptual framework for understanding and analyzing planning processes.

SPECIALISTS

Specialists embody knowledge about different kinds of planning decisions and when each kind is appropriate. The OPM operationalizes specialists as condition-action rules, for example, "IF <there is a requested errand near the current location>, THEN <record a decision to perform that errand next>." The condition component describes the circumstances under which the specialist can make a decision. The condition usually requires specific types of information to have been posted on the blackboard by other specialists, as well as the satisfaction of other, arbitrarily complex criteria. When the condition of a specialist has been satisfied, we say that the specialist has been "invoked." The action component specifies the specialist's decision-making behavior. Thus, specialists represent a set of heuristics for generating or modifying plan decisions based on recognized patterns of previous decisions.

BLACKBOARD STRUCTURE

As mentioned above, the blackboard contains five conceptual planes: plan, plan-abstraction, world-knowledge, executive, and metaplan. Each of these partitions records a different kind of planning knowledge. Figure 3 provides a graphic representation of the blackboard structure.

Plan, plan-abstraction, and world-knowledge decisions determine features of the developing plan. Decisions on the plan plane represent actions that the planner intends to take in the world, for example, going to the florist next, or traveling down Jackson Avenue to get to the bank. Decisions on the plan-abstraction plane characterize desired attributes of potential plan decisions, indicating the kinds of actions that the planner would like to take, without specifying the actions themselves. For example, the planner might decide to go to the closest errand next (without specifying the identity of that errand) or to organize the plan around spatial clusters of errands (without specifying the contents of those clusters). Decisions on the world-knowledge plane record observations and computations regarding relationships in the task environment that might bear on the final plan. For example, a world-knowledge decision might encode the fact that the florist is close to the current location, or that the bank, the shoe store, and the movie theater cluster together in the same neighborhood.

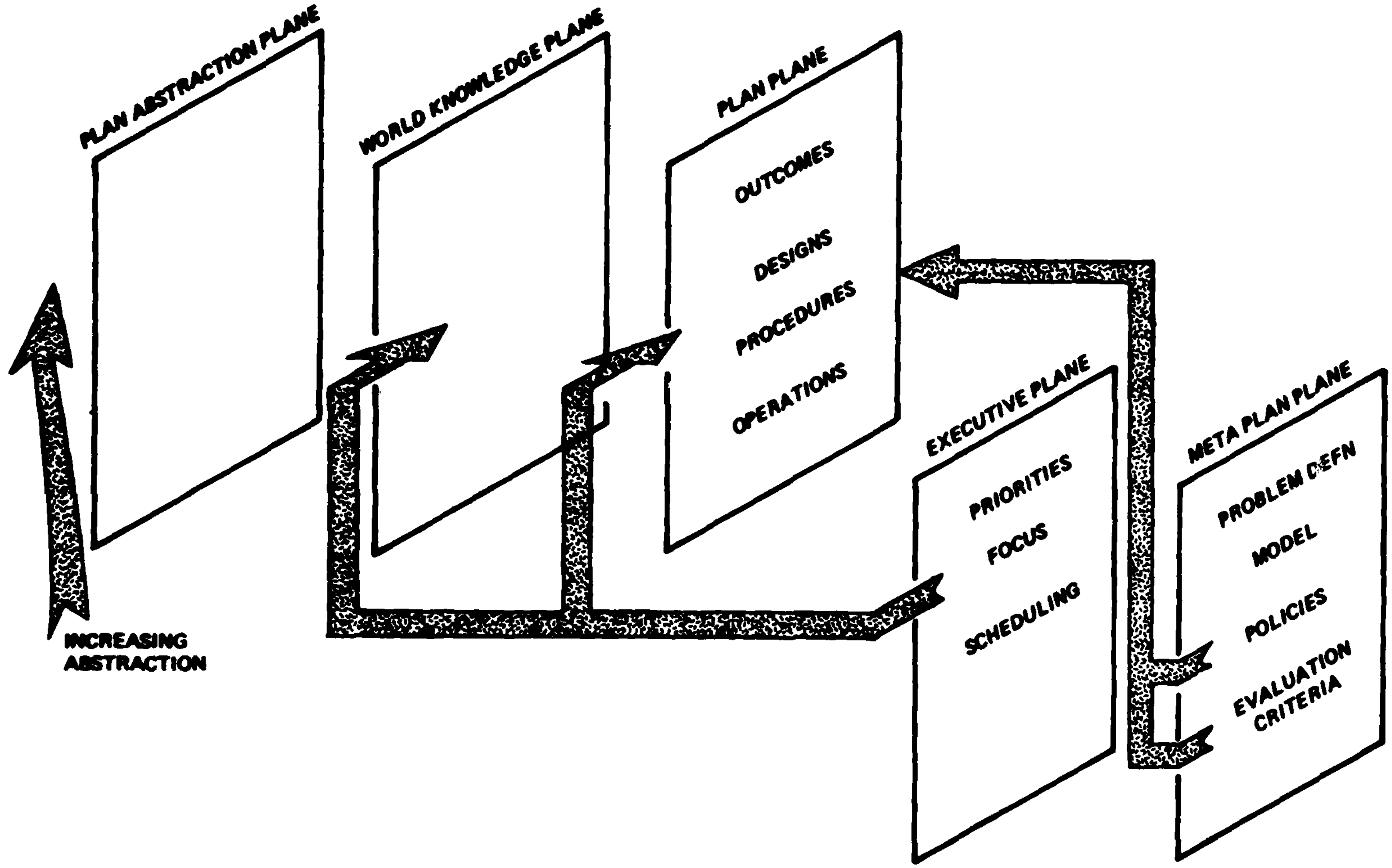

Fig. 3--Blackboard Structure in the Opportunisitc Planning Model

In contrast to the three planes discussed above, executive decisions determine the allocation of cognitive resources during the planning process: what kinds of decisions to generate first, what aspect of the plan to develop next, what specialist to bring to bear at a given point in the planning process. For example, the planner might make an executive decision to determine the best order for the errands before finding a route among them.

The metaplan plane contains more general decisions about how to approach the planning problem. Metaplan decisions reflect the planner's understanding of the problem, the methods he or she intends to apply to it, and the criteria he or she will use to generate and evaluate prospective plans.

As mentioned above, the OPM framework further partitions each plane into several levels of abstraction. The plan-abstraction, world-knowledge, and plan planes each have four levels of abstraction that form a potential hierarchy, with decisions at each level specifying a more refined plan than those at the next higher level. Decisions at the highest level determine a plan's <u>outcomes</u>: which errands will be accomplished when the plan is executed. For example, outcome decisions on the plan-abstraction, world-knowledge, and plan planes might be (a) I'll do all the most important errands; (b) the drugstore and the grocery are the most important errands; and (c) I'll definitely go to the drugstore and the grocery. Decisions at the next lower level determine the plan's <u>design</u>, the overall spatial-temporal organization of planned activities. For example, decisions on the three planes at this level might be (a) I'll organize the plan around spatial clusters of errands; (b) there is a cluster of errands in the southwest corner; and (c) I'll head toward the southwest cluster, doing errands on the way. Decisions at the next lower level determine the plan's procedures; that is, the ordering of individual errands. For example, three such decisions might be (a) I'll do the closest errand next; (b) the florist is closest; and (c) I'll go to the florist next. Finally, decisions at the lowest level of abstraction determine the plan's operations, the details of performing specific errands or traveling from one to another. For example, three such decisions might be (a) I'll take the shortest route to the next errand; (b) Belmont Street is the shortest route between the parking lot and the florist; and (c) I'll travel via Belmont Street to get to the florist.

The executive plane has three levels of abstraction. At the highest level, priority decisions establish principles for allocating cognitive resources during the entire planning process (e.g., I'll decide which errands to do before deciding when to do any of them). At the next lower level, focus decisions indicate what kind of decisions to make at a particular point in the planning process (e.g., Now I'll figure out the best route from the grocery to the drugstore). Finally, scheduling decisions resolve any remaining conflicts between competing invoked specialists, choosing a particular specialist to execute its action next.

The four levels of the metaplan plane, problem definition, problem-solving model, policies, and evaluation criteria, do not produce a neat hierarchy. However, they emphasize different aspects of the subject's approach to the planning problem: his or her representation of the task and its goals, resources and constraints (problem definition), the general strategy he or she assumes in generating a solution (problem-solving model), a set of global constraints and desirable features for the developing plan (policies), and a set of dimensions against which the planner can evaluate tentative plans (evaluation criteria).

CONTROL OF THE PLANNING PROCESS

The planning process proceeds through a series of cycles during which specialists read information from the blackboard and take subsequent action. On any cycle, a number of specialists may be invoked--that is, their conditions may have been satisfied by the appearance of some prior decision on the blackboard. An executive decision selects one of the invoked specialists to execute its action, generating a new decision and recording it on the blackboard. This new decision will invoke additional specialists, beginning a new cycle. The process will ordinarily continue until the planner has integrated mutually consistent decisions into a satisfactory plan.

IMPLICATIONS FOR INDIVIDUAL DIFFERENCES

While the OPM is not a theory of individual differences, it provides a framework for studying them. In particular, it suggests that individual differences might occur in any of three general areas: (a) the structure of the operational (as opposed to the theoretical) planning space; (b) the control processes used during planning; and (c) the specific planning knowledge used to solve problems. These three areas represent an exhaustive decomposition of planning functions within the OPM framework. Other models, however, might suggest additional sources of inter-individual variance that are not relevant in the OPM framework. A noncognitive model of planning, for example, might stress motivational differences, while alternative cognitive models might focus on short-term-memory capacity or the speed of mental transformations (cf. Pellegrino & Glaser, 1980).

The OPM model also suggests specific hypotheses in each of the areas listed above. Regarding the structure of the operational planning space, the model suggests that individuals may differ in their use of particular planes of the blackboard or particular levels of abstraction. Specifically, better planners should make fuller use of available decision categories. Regarding control processes, the model predicts that individuals may differ in their tendency to shift attention among planes, levels of abstraction, and temporal loci, as well as in their tendencies to use particular global executive strategies. Better planners may be more flexible in their allocation of attention. Also, they may exercise more conscious control over their focus of attention. Regarding planning knowledge, the model suggests that individuals may have different specialists to apply in certain areas of the blackboard. Better planners should have more knowledge about potential decisions at various planes and levels. In addition, they may possess some especially powerful knowledge about strategies or procedures to produce good plans.

The analyses described below investigated each of these hypothetical patterns of individual differences. The results of these analyses should not be construed as testing the OPM approach; however, they demonstrate the utility of the model in guiding new research.

III. METHOD

EXPERIMENTAL PROCEDURES

Five subjects (three females, two males) performed the errand-planning task described above. They worked six different problems (see Appendix) on six different days. Each subject worked on the problems in a different order. Subjects were self-paced and were permitted to write notes on the map, the problem description, or scratch paper, as they wished. Subjects were asked to think aloud, describing their observations, reasoning, thoughts, and decisions while developing their plan.

PLAN EVALUATION PROCEDURE

In order to assess individual differences in planning effectiveness, it was first necessary to operationalize the concept of a "good" plan. Whereas the solution in a cryptarithmetic or even a chess problem is fairly easy to define objectively, the "solution" to a planning problem is usually much less clear-cut. The _true_ effectiveness of a plan can be assessed only by executing that plan and observing the outcomes. Furthermore, even executing a plan may not provide a satisfactory evaluation of a planner's skill, since even the best of plans can go astray due to unanticipated events in the execution environment.

Our solution to this dilemma was to score subjects' plans independently on each of several evaluation criteria that intuitively seemed to characterize a "good" plan in our experimental task domain. These criteria included (a) accomplishment of many errands; (b) accomplishment of important errands; (c) realism of time estimates; (d) route efficiency; and (e) satisfaction of time constraints. We operationalized each component score on a 100-point scale. We then averaged these component scores to produce a single measure of overall plan goodness. While this aggregation rule was arbitrary, it was unbiased with respect to any individual evaluation dimension. In addition, we were able to examine trends in component scores as appropriate.

Table 1 lists the rules used to score plans against each criterion. Normative estimates of errand times, provided by an independent set of 20 subjects, enabled us to determine which errands in a plan could realistically be accomplished in the available time specified by the scenario. Starting at the beginning of the subject's plan, we traced

Table 1

RULES FOR SCORING PLANS AGAINST EVALUATION CRITERIA

Criterion	Rule
Number of Errands Accomplished	Score = % of requested errands planned and executable in available time
Number of Important Errands Accomplished	Score = % of important errands planned and executable in available time (Importance value > 4.0)
Realism	$\text{Score} = 100 - \dfrac{100 \times (\text{Time to execute plan} - \text{Time available})}{(\text{Time available})}$
Route Efficiency	$\text{Score} = 100 - \dfrac{100 \times (\text{Planned route length} - \text{Optimal route length})}{(\text{Optimal route length})}$
Explicit Constraint Satisfaction	Score = % of time-constrained errands specified in scenario that could be satisfied if the plan were executed

out the errands he or she had included, using normative time estimates rather than the subject's (often unrealistic) time specifications. Any errands not accomplished when the available time was exhausted were considered to be "unrealistic." In scoring a plan on number of errands accomplished, we included only realistic errands, that is, errands that fit into the available time interval. Similarly, in scoring a plan on the accomplishment of important errands, we considered only the realistic errands that had normative importance ratings (provided by the same set of 20 subjects) of at least 4 on a 5-point scale. We scored the plans against the other criteria in similar fashion.

PROTOCOL CODING TECHNIQUES

The first author scored the protocols as follows. First, she segmented the protocol into sections, each of which expressed a single decision. As discussed above, we assume that subjects can make many different kinds of decisions, corresponding to the levels and planes of the planning blackboard. Thus each decision segment of a protocol can be viewed as a single addition to, or modification of, the current contents of the planning blackboard. We do not necessarily assume that all decisions in the planning sequence are explicitly represented in the protocols. However, in contrast to some other protocol coding methods (cf. Newell & Simon, 1972), we chose to analyze only the surface content of the protocols, that is, decisions that were openly verbalized, rather than infer the content of subjects' covert processing.

Each decision segment was then coded in an attribute-value representation. The following attributes were coded for all decisions: (a) the plane of the blackboard on which the decision would be recorded;

(b) the level of abstraction at which the decision would be recorded; (c) a "type" specifying the generic content of the decision. (The specific tags will be described in detail in the discussion of planning knowledge below.) Additional attributes specified other details of decisions. For example, decisions that added errands or route segments to the plan included a "plan-location" attribute to indicate whether that errand would be ordered "next" in the plan or at some time earlier or later than the current time focus.

The second author analyzed several randomly selected protocols as a check on reliability. The two coders agreed on over 90 percent of both segmentation decisions and attribute-value codings. Figure 4 shows an excerpt from a segmented protocol, and Figure 5 shows the corresponding coded decisions.

ANALYSIS

As discussed above, we investigated several hypotheses. Each hypothesis related the frequency of a particular class of decisions to plan goodness scores. We evaluated the hypotheses with simple correlational techniques, measuring how closely each class of decision is related to plan goodness. The correlations are intended to be descriptive only. With so few subjects, it makes little sense to talk about statistical significance. We arbitrarily set .75 as a cutoff point for an "interesting" relationship--one which merits further investigation. The data will be discussed in terms of the size of the correlations relative to this criterion rather than in terms of significance.

9. The dance class, being an hour,
just might have to get eliminated

10. because that's too much time.
I don't know.

11. We'll try and fit that in.
Give it a secondary for now.

12. So, let's run down the items,
where they are.

13. Ice cream sitting here
about the center of town.

14. Birthday cake is in
the north side of town.

15. Decorations at department store.

16. Well, now we can see a pattern developing.

17. We can go from the ice cream store to the
department store to the bakery.

18. Ball glove is way over here in
the east side of town.

19. There's a pharmacy here on
the west side of town.

20. The lawyer's office is in
the west side of town.

21. So probably again a northwesterly sweep
might be able to get things done.

Fig. 4--A Sample Protocol Excerpt from
the Errand-Planning Task

```
PLANE plan LEVEL outcomes TYPE revise ELEMENTS dance class
   eliminated REASON E10 REALITY possible EVENT 9

PLANE planabstr LEVEL outcomes TYPE omit ELEMENTS long errands
   EVENT 10

PLANE worldknowl LEVEL outcomes TYPE consider-priorities
   ELEMENTS dance class PRIORVAL low EVENT 11

PLANE exec LEVEL focus TYPE locate-errands
   FOCUSED neighbors EVENT 12

PLANE worldknowl LEVEL procedures TYPE locate-errands
   ELEMENTS ice cream at center of town EVENT 13

PLANE worldknowl LEVEL procedures TYPE locate-errands
   ELEMENTS cake at N side of town EVENT 14

PLANE worldknowl LEVEL procedures TYPE locate-errands
   ELEMENTS decorations at dept store EVENT 15

PLANE worldknowl LEVEL designs TYPE detect-layout EVENT 16

PLANE plan LEVEL designs TYPE generate
   ELEMENTS ice cream to dept store to bakery EVENT 17

PLANE worldknowl LEVEL procedures TYPE locate-errands
   ELEMENTS sporting goods on E side of town EVENT 18

PLANE worldknowl LEVEL procedures TYPE locate-errands
   ELEMENTS pharmacy on W side of town EVENT 19

PLANE worldknowl LEVEL procedures TYPE locate-errands
   ELEMENTS lawyer on W side of town EVENT 20

PLANE plan LEVEL designs TYPE generate
   ELEMENTS northwesterly sweep EVENT 21
```

Fig. 5--Coded Representation for Sample Protocol Excerpt

IV. RESULTS AND DISCUSSION

PLAN GOODNESS SCORES

Theoretically, individuals' planning scores could range from 0 to 100. Actually, the range of variation was considerably less; however, individual differences in planning effectiveness were still clearly apparent. We tested for the existence of inter-subject differences by performing a one-way analysis of variance on individual subjects' plan score residuals (score for a particular scenario minus mean for that scenario over subjects). This analysis removed the variance associated with differences between scenarios. The analysis corroborated our intuitions by showing a significant main effect of subjects ($F(4,25) = 5.89$, $p<.01$, $MS_e = 57.4$). Neuman-Keuls comparisons indicated that the best subject's plan scores differed significantly from all the other subjects ($p<.05$), who produced equivalent scores. Thus, significant differences in planning effectiveness can be found even in a small sample such as ours.

INDIVIDUAL DIFFERENCES IN THE USE OF THE BLACKBOARD

As discussed above, the OPM suggests that individuals may differ in the structure of their operational planning space, that is, the frequency of decisions on each plane and level of abstraction on the blackboard. Table 2 shows these data.

The upper panel of Table 2 shows the mean frequency per protocol of decisions on each of the five planes of the planning blackboard. These data show that good planners made more executive and metaplan decisions than poor planners. These two planes describe meta-cognitive activity: awareness and control of the planning process. Planners who made

Table 2

INDIVIDUAL DIFFERENCES IN OPERATIONAL PLANNING SPACE

Locus of Decision	Individual Plan Score: Best 76.7	2 62.7	3 60.9	4 60.8	Worst 53.3	Correlation Coefficient	
Decisions on Each Plane							
Plan	68.7	37.5	48.2	34.4	54.8	.68	
World Knowledge	25.3	16.8	5.7	10.1	14.7	.78	<<
Plan Abstraction	6.5	3.7	3.5	1.2	6.0	.47	
Executive	8.0	1.5	.2	1.5	1.2	.96	<<
Metaplan	16.0	8.2	7.8	8.8	6.3	.99	<<
Decisions at Each Level of Abstraction							
Outcomes	28.7	16.0	4.8	11.3	11.2	.89	<<
Designs	6.2	3.8	1.3	2.2	2.5	.90	<<
Procedures	47.0	19.0	22.3	34.2	21.7	.73	
Operations	15.8	17.5	17.5	24.0	20.5	-.72	

conscious attempts to optimize their planning methods produced better plans. These data agree nicely with the Thorndyke and Stasz (1980) finding that subjects who showed more metacognitive activity performed better in map learning.

The data displayed also show that good planners used world knowledge more frequently than poor planners. Intuitively, one would expect a good planner to exploit available information about the plan execution environment. That is exactly what we observed.

The lower panel of Table 2 shows mean frequencies of decisions at each level of abstraction on the plan, plan-abstraction, and world-knowledge planes. These data show that good planners made more high-level decisions than poor planners. Specifically, effective planners made more decisions about the intended outcomes and overall design of the plan. These results suggest that good planners tended to take a more global approach than poor planners in developing their plans. This is consistent with research on skill-level differences in other domains (cf. Chase & Chi, 1979). Skill in chess (Chase & Simon, 1973(a,b)), in baseball knowledge (Chiesi et al., 1979), in electronics (Egan & Schwartz, 1979), or in physics (Chi & Glaser, 1979) is associated with perception of larger or more global configurations of domain elements.

INDIVIDUAL DIFFERENCES IN CONTROL PROCESSES

The OPM can accommodate many different global control strategies, such as top-down successive refinement (Sacerdoti, 1974), constraint-driven plan-generation (Stefik, 1980), or data-driven plan generation (Simon & Simon, 1978). Good planners might exhibit more effective control strategies than poor planners. However, we have found it difficult to operationalize control strategies in such a way that they make distinctive predictions about simple frequency distributions. Characterization of particular control strategies implicit in our protocols would require consideration of the sequence in which a planner generates individual decisions and the conceptual relationships among decisions.

For the present, therefore, we restrict our investigation to one of the grosser features of control processes: attentional flexibility. The OPM suggests that individuals may differ in their tendency to shift attention among different loci on the planning blackboard. We measured three types of attentional flexibility: (a) the number of decisions whose plane differs from the plane of the preceding decision; (b) the number of decisions whose level of abstraction differs from the level of the preceding decision; and (c) the number of decisions planned for a temporal locus other than the one directly succeeding the previously planned errand (that is, the number of decisions whose plan-location attribute was not "next").

Table 3 shows mean frequencies for all three measures of attentional flexibility. Good planners shifted from one plane to another more frequently than poor planners. Good planners also exhibited more flexibility in time focus. Finally, the total number of changes of attention (bottom line) does distinguish good from poor planners.

Thus, there is some evidence that good planners show greater attentional flexibility than poor planners. This seems reasonable; switching from one aspect of the plan to another, considering multiple sources of information and multiple constraints, should result in a more complete understanding of the planning problem. It is also possible that good planners redirect their attention more effectively than do poor planners. The analysis of differences in operational planning structure showed that good planners made more decisions regarding the focusing of attention (executive decisions). In the discussion of executive knowledge below, we consider differences in the specific attention-focusing decisions made by good and poor planners.

Table 3

DECISIONS THAT CHANGE ATTENTIONAL FOCUS

Type of Change	Individual Score Plan					Correlation Coefficient
	Best	2	3	4	Worst	
	76.7	62.2	60.9	60.8	57.5	
Change in Plane	80.7	43.7	42.0	38.3	55.3	.83 <<
Change in Level of Abstraction	37.0	23.2	32.2	15.7	30.5	.53
Change in Time Focus	18.3	4.3	10.8	6.3	10.5	.75 <<
All Changes	136.0	111.2	85.0	60.3	86.3	.80 <<

INDIVIDUAL DIFFERENCES IN PLANNING KNOWLEDGE AND DECISION CONTENT

The OPM suggests that individuals may also vary in the specific knowledge they bring to bear on a planning task and, consequently, in the content of their decisions. Good planners may differ from poor planners in the amount of planning knowledge they possess or in their use of particularly powerful or effective knowledge.

Our protocol analyses captured this specific knowledge in the "type" attribute which encoded the generic content of individual decisions. The assignment of types was an iterative process; inspection of the protocols led to the enumeration of a set of types which were then used to code individual decisions. Once again, the first author performed the original coding. The second author spot-checked this coding, with over 90 percent agreement. Obviously, the specific types that subjects used differed across the blackboard planes. Below we discuss types and their associated statistics separately for each plane.

Plan Decisions

We observed six types of decisions regarding the plan *per se*. Each of these decision types performs a different function in producing or modifying some component of the developing plan. All of them operate on information recorded on the plan plane and/or record their results on that plane. "Generate" decisions extend or elaborate on the plan (e.g., deciding to go to the florist next). "Evaluate" decisions assess previous plan decisions relative to some set of evaluation criteria (e.g., deciding whether a previously chosen route is efficient). "Compare" decisions simultaneously evaluate and choose between two alternative actions (e.g., deciding that it is better to go to the drugstore after the grocery rather than before). "Monitor" decisions perform bookkeeping functions (e.g., deciding how much time remains for additional unplanned actions). "Review" decisions recall previously planned actions or the results of previous decisions (e.g., recalling a decision to omit a movie from the day's errands). Finally, "revise" decisions change the current plan (e.g., deciding to eat lunch at the Oak Street restaurant rather than the Washington Street restaurant).

Table 4 shows mean frequencies for each type of plan decision. These results indicate that good planners reviewed and evaluated their plans more often than poor planners. This seems reasonable; periodic evaluation of the developing plan would enable the planner to detect weaknesses and change the plan accordingly. In the present case,

Table 4

DECISION TYPES ON THE PLAN PLANE

	Individual Plan Score					
	Best	2	3	4	Worst	
Type of Decision	76.7	62.2	60.9	60.8	57.5	Correlation Coefficient
Generate	28.7	17.6	23.8	17.5	23.5	.65
Compare	2.8	.2	.7	.3	1.5	.75 <<
Monitor	18.5	13.7	18.5	13.2	20.3	.11
Review	6.8	1.5	.8	.8	3.0	.84 <<
Evaluate	6.3	3.8	1.7	1.3	.8	.93 <<
Revise	4.7	.7	2.7	1.2	3.8	.52

however, evaluation decisions do not seem to serve this function; good planners did not revise their plans more frequently than poor planners. This finding may reflect a tendency for good planners to generate a better plan in the first place. Frequent evaluation of plan components may allow good planners to reject faulty decisions before actually including them in the plan, thereby avoiding the need for many revisions. In other words, good planners may tend to evaluate their decisions while they are still <u>tentative</u>.

Some evidence for this hypothesis can be found in the protocols. Our coding scheme included a "reality" attribute to indicate when a subject's decisions were explicitly stated as tentative or hypothetical rather than definite. Frequency analysis of this attribute indicated that the number of "tentative" decisions did increase with overall planning scores ($r = .79$). Since changes in "tentative" decisions were not coded as "revise" decisions, they did not increase the frequency of "revise" decisions for good planners. Thus, another characteristic distinguishing good from poor planners is their reluctance to commit themselves to a decision until they have evaluated its consequences. Good planners also tended to compare alternative plan actions more frequently than poor planners. This finding can also be viewed as indicating a "wait-and-see" attitude, an awareness of available options and a willingness to suspend firm decisions until all options are evaluated. Good planners apparently avoid snap judgments. They may also attempt to optimize their plans more consciously and deliberately than poor planners.

Plan-Abstraction Decisions

We observed nine different types of plan abstraction decisions, as discussed below.

Three decision types characterize the intended outcomes of the plan. "Omit" decisions indicate an intention to eliminate from the list of planned outcomes errands that possess undesirable attributes (e.g., too far away, not very important). "Include" decisions indicate an intention to add to the list of planned outcomes errands that possess desirable attributes (e.g., very important). "Replace" decisions indicate an intention to substitute one errand for another on the list of planned outcomes, due to some critical attributes of the errands involved (e.g., their relative importance).

Two decision types describe an intended design for the plan. "Cluster" decisions indicate an intention to design the plan around clusters of errands located in close proximity to each other. "Trajectory" decisions indicate an intention to travel according to a particular pattern or in a particular overall direction (e.g., work from northeast to southwest).

Four decision types determine the kind of procedures that will be used to order errands. "Choose-location" decisions describe strategies for choosing among several alternative sites for an errand (e.g., choose a location close to the starting location). "Choose-next-errand" decisions describe strategies for choosing which errand to plan next (e.g., do the closest errand next). "Assign-window" decisions describe strategies for allocating a particular errand to some time slot other than "next" (e.g., buy perishables later). Finally, "assign-anchor" decisions describe strategies for planning to do an errand at a particular time (e.g., go to appointments at the assigned time).

We did not observe any explicit plan-abstractions that described the operations level of a plan. It may be that perceptual or other rapid and automatic processes are responsible for these low-level decisions.

Table 5 shows mean frequencies for each type of plan-abstraction decision. Good planners made more of all three types of outcome-level decisions. Apparently, good planners were more aware of the need to select some errands for inclusion in the plan and to exclude others. Good planners also made more "assign-window" decisions than poor planners. This suggests that good planners sometimes form "loose" initial plans, which they subsequently refine, while poor planners form

Table 5

DECISION TYPES ON THE PLAN-ABSTRACTION PLANE

Type of Decision	Individual Plan Score: Best 46.7	2 62.2	3 60.9	4 60.8	Worst 52.5	Correlation Coefficient	
Outcomes							
Omit	2.0	1.0	.7	.2	.2	.94	<<
Include	.5	.2	0	0	.2	.82	<<
Replace	.2	0	0	0	0	.97	<<
Designs							
Cluster	.2	.3	0	0	0	.52	
Trajectory	.2	.3	.3	.2	.2	-.25	
Procedures							
Choose-location	.5	.2	.3	.2	.8	.00	
Choose-next-errand	1.3	.8	2.0	.3	1.5	.02	
Assign-window	1.0	.7	.2	.2	.5	.77	
Assign-anchor	.2	.2	.2	0	0	.54	
Number of Decision Types Used at Least Once	9	8	6	5	6	.79	<<

more specific plans from the start. The tendency of good planners to make "tentative" decisions, mentioned above, is consistent with this hypothesis.

The last line in Table 5 indicates the number of different types of plan-abstraction each subject generated at least once across the six protocols. Based on this measure, good planners have a larger repertoire of plan-abstraction knowledge than poor planners. This result is similar to the Thorndyke and Stasz (1980) finding that good map learners had more varied repertoires of spatial learning techniques.

World-Knowledge Decisions

We observed six different types of world-knowledge decisions, as discussed below.

Three decision types provide information useful in establishing the intended outcomes of the plan. "Consider-errand-priorities" decisions assign importance values to individual errands. "Consider-errand-constraints" decisions establish explicit or implicit restrictions on when or how certain errands could be accomplished. "Estimate-time" decisions indicate how much time would be required to accomplish an errand.

Two decision types provide information useful in generating an overall design for the plan. "Define-clusters" decisions locate and identify the elements of spatial clusters of errands on the map. "Survey-errand-distribution" decisions examine the overall pattern of requested errand sites on the map.

Three decision types provide information useful in generating procedure-level sequences of errands. "Locate-errands" decisions identify the locations of individual errands on the map. "Consider-sequencing-constraints" decisions establish restrictions on the ordering of errands. "Estimate-sequence-times" decisions indicate how much time would be required to execute a planned sequence of errands.

Finally, one decision type provides information useful in generating specific routes at the operations level. "Estimate-route-times" decisions indicate how much time would be required to traverse a planned route.

Table 6 shows the mean frequencies for type of world-knowledge decisions. Three decision types distinguished between good and poor planners. Good planners made more "consider-errand-constraints," "define-clusters," and "consider-sequencing-constraints" decisions.

Table 6

DECISION TYPES ON THE WORLD-KNOWLEDGE PLANE

	Individual Plan Score					
	Best	2	3	4	Worst	
Type of Decision	76.7	62.2	60.9	60.8	57.5	Correlation Coefficient
Outcomes						
Consider-priorities	7.0	7.5	0	0	2.7	.59
Consider-errand-constraints	.3	.2	0	0	0	.86 <<
Estimate-errand-times	1.7	.2	.5	.2	1.7	.41
Designs						
Define-clusters	1.7	1.0	.2	.2	.7	.82 <<
Survey-errand Distribution	0	.5	.2	0	.2	-.40
Procedures						
Locate-errands	12.0	4.7	2.8	7.8	7.2	.73
Consider-sequence-constraints	.2	0	0	0	0	.97 <<
Estimate-sequence-times	.2	.5	.2	0	0	.22
Operations						
Estimate-route-times	0	0	.2	0	0	-.20
Number of Decision Types Used at least Once	7	7	6	3	5	.52

None of the other decision types distinguished good from poor planners, nor did the overall number of different types of decisions made vary with planning skill (see bottom line of Table 5). Thus, good planners' more frequent use of world knowledge, noted above, can be attributed to their greater sensitivity to constraints on when certain errands could be performed and to their efforts to identify spatial clusters of errands.

Executive Decisions

Decisions on the executive plane differ from those on other planes because their major function is to determine the sequence of decisions on other planes. Thus, their content refers to actions that will be taken on these other planes. All the executive decisions that we observed represented the "focus" level of abstraction. That is, they all specified what kind of decision the planner intended to make next.

Table 7 presents the mean frequencies for each type of focus decision. The upper panel shows decisions that focus on the world-knowledge plane (i.e., that indicated an intention to make a subsequent decision on the world-knowledge plane). The lower panel shows decision types that focus on the plan plane. (We observed no decisions that focused on other planes of the planning blackboard.) Decisions in both panels are organized by level of abstraction. There are too many decision types to discuss them individually; however, most of them are self-explanatory.

Table 7 shows that almost every type of focus decision was strongly related to plan goodness. However, the high correlations shown in this table reflect a quantal rather than a graded difference between good and

Table 7

DECISION TYPES ON THE EXECUTIVE PLANE

	Mean Individual Plan Scores					
	Best	2	3	4	Worst	Correlation
Type of Decision	76.7	62.2	60.9	60.8	57.5	Coefficient
Focus on World-Knowledge Plane						
Outcomes						
Evaluate-errands	.5	.2	0	0	0	.95 <<
Estimate-time	.3	0	0	0	0	.97 <<
Designs						
Detect-layout	.7	.5	0	0	0	.84 <<
Procedures						
Locate-errands	.5	.5	.7	1.2	0	-.14
Find-errands-near-path	.2	0	0	0	0	.97 <<
Choose-location	.7	0	0	0	0	.97 <<
Set-errand-time	.2	0	0	0	0	.97 <<
Locate-primary-errands	.2	0	0	0	0	.97 <<
Find-nearby-errands	.3	0	0	0	0	.97 <<
Estimate-time	1.5	0	0	0	0	.97 <<
Coordinate-times	.2	0	0	0	0	.97 <<
Operations						
Estimate-times	.3	0	0	0	0	.97 <<
Focus on Plan Plane						
Outcomes						
Choose-errands	.3	0	0	0	0	.97 <<
Eliminate-errands	.2	0	0	0	.2	.42
Errand-survey	0	0	.2	0	0	-.20
Design						
Make-plan	.2	0	0	0	0	.97 <<
Procedures						
Choose-errands	.2	0	0	0	0	.97 <<
Make-plan	.2	0	0	0	0	.97 <<
Compare-alteratives	.2	0	0	0	0	.97 <<
Order-errands	.2	.2	0	0	0	.71
Generate-procedure	.3	.2	0	0	0	.86 <<
Evaluate-plan	.2	0	0	0	0	.97 <<
Find-next-errand	.2	0	0	.3	.2	-.14
Operations	.7	0	0	0	.2	.97 <<
Evaluate-plan	0	0	0	0	.2	-.46
Generate-route	.3	0	0	0	0	.97 <<
Review-plan	.2	0	0	0	0	.97 <<
Make-plan	.2	0	0	0	0	.97 <<
Number of Decision Types Used at Least Once	25	5	1	2	5	.94 <<

poor planners: For most decision types, good planners made a few executive decisions, while poor planners did not make any at all. The most informative data appear in the bottom line of Table 7. The number of decision types that appeared at least once in each subject's protocols was strongly related to plan goodness. Thus, in addition to showing greater attentional flexibility, as discussed above, good planners were more purposeful in their redirection of attention, justifying this redirection with a greater variety of reasons.

Metaplan Decisions

We observed seven types of decisions that occurred at both the policy and evaluation criteria levels of the metaplan plane. All these decision types represent implicit knowledge about the desirable features of a good plan. "Do-many-errands" decisions emphasize accomplishing a large proportion of the requested errands. "Do-important-errands" decisions emphasize accomplishing the most urgent or critical errands. "Travel-efficiently" decisions emphasize traveling the shortest distance possible. "Be-realistic" decisions emphasize estimating errand times to allow execution of the plan in the time available. "Satisfy-time-constraints" decisions emphasize arriving at time-constrained errands (e.g., a dentist appointment at 4:30 PM) at the specified time. "Satisfy-implicit-constraints" decisions emphasize performing certain categories of errands at appropriate times, based on preexisting knowledge about these classes of errands (e.g., getting perishables last). Finally, "use-time-efficiently" decisions emphasize using the available time to perform errands and avoiding empty "waiting" periods.

We observed the same decision types at both the policy and evaluation criteria levels because both these levels contain decisions about the general characteristics of a good plan. Decisions at the two levels differ in the functions they serve during the planning process. Policy decisions establish standards for plan development. Evaluation criteria decisions establish criteria for evaluating previously generated plan decisions. Because all types of policy decisions occurred with low frequency, we collapsed policy and evaluation criteria for this analysis.

Table 8 shows that good planners generated almost every type of metaplan decision more frequently than poor planners. The only exceptions are the "do-many-errands" and "satisfy-implicit-constraints" decision types. The former decision type is a very elementary criterion which, if strongly enforced, would produce plans that violated several other criteria. Thus, effective planning may involve the recognition that tradeoffs must be made between doing many errands and satisfying other criteria. The latter decision type occurred less frequently overall than any other criterion (six times in 30 protocols) and in fact was relevant in only two scenarios.

The bottom line in Table 8 shows the number of metaplan decision types used by each subject in at least one protocol. Based on this measure, the amount of metaplan knowledge does not seem to differentiate good and poor planners. Four of the five subjects used at least six of the seven decision types. Thus, it was not knowledge about the attributes of a good plan that distinguished good planners from poor planners, but rather the frequency with which they used this knowledge. This point is reinforced by the finding reported above that good planners evaluated their plans more often than poor planners.

Table 8

DECISION TYPES ON THE METAPLAN PLANE

Type of Metaplan Knowledge	Individual Plan Score Best 76.7	 2 62.7	 3 60.9	 4 60.8	 Worst 57.5	Correlation Coefficient	
Do-many-errands	.7	1.2	.7	.3	.2	.29	
Do-important-errands	.8	0	.2	0	0	.95	<<
Travel-efficiently	1.3	.5	.2	.2	0	.98	<<
Be-realistic	2.8	.5	.5	.2	.3	.98	<<
Satisfy-time-constraints	1.3	.7	.5	.2	.5	.89	<<
Satisfy-implicit-constraints	.3	.3	.2	.2	0	.65	
Use-time-efficiently	1.5	.8	.2	.2	0	.94	<<
Number of Decision Types Used at Least Once	7	6	7	6	3	.58	

It is interesting to note that five of the seven criteria subjects used corresponded to the five component measures of our plan goodness scores. This provides an opportunity to "validate" the protocol analysis as a reflection of subjects' actual planning processes. If use of these evaluation criteria mediates plan development and revision, we should find strong relationships between the frequency with which each criterion was used and the scores on the corresponding component of the plan goodness measure.

The results of this analysis, shown in Table 9, confirm the predicted relationship for four of the five criteria. Only "do-many-errands" failed to produce a substantial correlation. The corresponding component score also produced the smallest amount of between-subjects variability. This suggests that all planners try to maximize the number of errands accomplished, but that good planners also try to satisfy additional criteria. These include the four criteria we used to score the plans and two others as well (use-time-efficiently and satisfy-implicit-constraints.)

Table 9

RELATIONSHIP OF COMPONENT DIMENSIONS OF PLAN SCORE TO FREQUENCY OF CORRESPONDING METAPLAN DECISION

	Individual Plan Score					
	Best	2	3	4	Worst	Correlation of Component with Frequency
Criterion	76.7	62.2	60.9	60.8	57.5	
Do-many-errands						
Component Score	63.3	58.3	57.2	69.2	64.8	-.19
Decision Frequency	4	7	2	4	1	
Do-important-errands						
Component Score	79.2	69.5	75.2	61.2	65.3	.80 <<
Decision Frequency	5	0	1	0	0	
Travel-efficiently						
Component Score	86.5	81.8	78.7	73.8	65.3	.78 <<
Decision Frequency	8	3	0	1	0	
Be-realistic						
Component Score	90.2	63.2	60.8	61.7	53.2	.96 <<
Decision Frequency	17	3	3	1	2	
Satisfy-time-constraints						
Component Score	50	16.7	8.3	16.7	27.7	.82 <<
Decision Frequency	8	4	3	1	3	

V. CONCLUSIONS

The present study has produced evidence for individual differences in the three areas suggested by the opportunistic planning model. These results are summarized briefly below:

1. Good planners exhibited more comprehensive operational planning structures than poor planners. In particular, good planners made more metaplan decisions (to establish criteria for plan generation and evaluation), executive decisions (to control the allocation of cognitive resources during planning), and world-knowledge decisions (to assess data relevant to planned actions). Ironically, executive and metaplan decisions are in some sense the most abstract decisions a planner can make, while world-knowledge decisions are the most concrete. This suggests that good planners' behavior is both more structured and more flexible than poor planners' behavior. Good planners control their planning behavior with consciously generated meta-cognitive strategies and criteria while remaining open and responsive to a variety of data.

Good planners also made more decisions at higher levels of abstraction with respect to the plan itself. In particular, they made more decisions concerning the intended outcomes of the plan and more decisions concerning an overall temporal-spatial design for the plan. These decisions serve two purposes. First, they implicitly serve two evaluation criteria: (a) do-important-errands; and (b) travel-efficiently. Second, they provide simplified "rough plans" to guide subsequent plan development. Note, however, that these results do not imply that good planners followed a strictly top-down control strategy. High-level decisions appeared throughout the subjects' protocols. Some preceded related lower-level decisions, while others followed them. Good planners tend to make more decisions on higher levels of abstraction, but these decisions do not completely constrain lower-level decisions. As assumed by the opportunistic planning model, lower-level decisions sometimes suggest subsequent higher-level decisions, as well as refining previous higher-level decisions.

2. Good planners exhibited more attentional flexibility than poor planners. In addition, good planners were more likely to maintain conscious control over their focus of attention, and they generated a greater variety of executive decisions. Thus it appears that good planners controlled their focus of attention more effectively than poor planners.

3. Good planners also differed from poor planners in their use of specific knowledge. We observed such differences for decisions on all five planes of the blackboard. Regarding the plan itself, good planners more frequently reviewed and evaluated their previous decisions. They also compared alternative plan actions more frequently. In their use of world knowledge, good planners were more sensitive to constraints on when certain errands could be done and to the existence of spatial clusters of errands. Good planners had larger repertoires of plan-abstraction decisions, and they used several types of plan abstractions more frequently than poor planners did. Regarding executive decisions, good planners generated a great number and variety of focus decisions, while poor planners generated only a few. Finally, although good planners and poor planners used essentially the same criteria for generating and evaluating their plans (metaplan decisions), good planners used most of these criteria more frequently than poor planners did. Thus, in general, good planners had larger repertoires of planning

knowledge than poor planners and exploited particularly powerful pieces of knowledge more effectively.

These results suggest a clear pattern of individual differences between good and poor planners. Of course, our conclusions must be considered tentative, since they are derived from a single task, using a small number of subjects. Furthermore, our conclusions are only descriptive, based on observed correlations between planning protocol characteristics and plan goodness scores.

Given these caveats, our results seem encouraging. Most of the differences between good and poor planners that we have identified reside in consciously controlled processes. In fact, one major characteristic distinguishing good from poor planners is the degree to which they consciously monitor and control their plan development. Consciously controlled processes are often amenable to training (Hunt, 1978). Thus, we may be able to train poor planners in specific strategies and knowledge and hence improve their planning performance. Such a training study could validate the descriptive research reported here by replicating our findings in an experimental design. In addition, a training study might produce some practical guidelines for improving general planning skills through training and instruction.

The general description of planning skill presented here is only a first attempt at characterizing individual differences in planning. Further studies that manipulate through training the planning knowledge available to planners or the characteristics of planning scenarios should produce new insights into the nature of expertise in planning. The analyses described here offer only a glimpse into the mechanisms which determine planning effectiveness--but it is a bright view.

Appendix

ERRAND-PLANNING SCENARIOS

Scenario 2

You have just finished your piano lesson at the music school and have many errands to do before going home. Your 2-week vacation starts next week and you still have not made any plans other than deciding on Mexico as your destination. You need to see a travel agent about the arrangements. You need to buy a Spanish phrasebook to help you through the language barrier. This is the perfect time to buy a new outfit at one of the fine clothes stores and a new pair of shoes at one of the shoe stores. Your watch just broke and you need to take it to be repaired. The exchange rates are quite low today and you want to take advantage of this by stopping by one of the banks and buying some foreign currency. You need to consult with your lawyer about buying some property. He said this morning was a good time to come by. The sports equipment store has what you've been looking for in diving equipment and you'd like to take this along on your trip. And before you go, you got a ticket for making an unsafe pass on the freeway and need to go the courthouse and pay the fine. Your father's birthday is also next week and you need to get him a card.

It's now 9:30 and you have until noon to do all these things. At noon you have to be at the subway stop so you will arrive home in time to meet a delivery.

You probably won't be able to do everything, but do the best you can. Remember you can you the errands in any order you choose. You are on foot and it takes 15 minutes to cross town in either direction.

Errand List

music school 82
plan vacation at travel agency 26
buy Spanish phrasebook at bookstore 14, 86, 32
buy new outfit at one of the fine clothes stores
    men's: 43, 38 women's: 47, 53
buy new shoes at one of the shoe stores 51, 67
take watch to watch repair 88
buy foreign currency at bank 48, 65
consult with lawyer about buying real estate 62
buy diving equipment at sports equipment store 29
pay fine for traffic ticket at courthouse 36
buy birthday card for father 60
subway 50

Scenario 3

It's now 9:30 am and you will be finished with your haircut appointment in 15 minutes. You are planning your day's errands and have to do as many things on your list as possible before being at the Washington Street parking lot by 12:00.

You are traveling by foot and it takes 15 minutes to cross town in either direction. Here's your list of errands. You are free to do them in any order you like.

hair salon 84
Washington Street parking 42

<u>Errand</u> <u>List</u>

buy record at one of the record stores 78, 22
buy air letters at Post Office 23
buy shoes at one of the shoe stores 51, 67
take watch to be repaired at watch repair 88
consult with lawyer about income tax 62
look at furniture at one of the furniture stores 69, 37
buy tennis racket at sports equipment store 29
buy fresh vegetables and cold cuts at one of the grocery stores 9, 87
buy fish food at pet store 28
fill prescription at one of the drug stores 6, 63
buy bread at bakery 16
buy books for art history class at one of the bookstores 32, 86, 14

Scenario 4

You just arrived at the parking lot on Maple Street. You have many errands to do before going to your tennis game at 2:00. It's 11:00 and you may not be able to do everything but do the best you can. The order in which you do them is up to you. You will do all these errands on foot, and it takes 15 minutes to cross town in either direction.

You need to xerox your income tax forms. You are redecorating your kitchen and need to get fabric for curtains and get curtain rods at the hardware store. Although you will buy the curtain rods today you are only going to compare prices and quality at the fabric store and both department stores. There are some items at Truc which you also want to include in your new kitchen, so you need to stop by there. You need to fill a prescription at one of the drug stores. A check from the insurance company arrived in the mail today and you want to deposit it in your bank on Jackson Avenue. Today is the last day of the history exhibit at the museum, so you want to stop by there. You are thinking of buying a new car and want to stop by the car dealer and see what is available and at what price. You also need mailing envelopes from the office supply store and paint brushes from the art supply store.

<u>Errand</u> <u>List</u>

Maple Street parking 80
xerox income tax forms at xerox shack 25
compare prices and quality at fabric store and
    BOTH department stores 15, 57, 77
buy curtain rods at hardware store 95
buy kitchen items at Truc 66
fill prescription at one of the drug stores 6, 63
deposit check at bank on Jackson Avenue 65
see exhibit at museum 27
check out cars at car dealer 10
buy mailing envelopes at office supplies 76
buy paint brushes at art supply store 30
tennis courts 98

Scenario 5

You've arrived by subway and have a number of things to do today before meeting your spouse at one of the restaurants at 6:30 pm. Your dentist appointment is at 4:30 and will take up 45 minutes. You will be visiting a neighbor in the hospital. The visiting hours at the hospital are 12-1, 2-5, and 6-8. All the stores close at 5:45 except the ticket outlet, the department stores, and the liquor stores. The time now is 3:30.

The errands can be done in any order you like. Remember, the plan also includes the restaurant at which you will meet your spouse.

Errand List

subway stop 50
buy calendar at office supplies 76
dentist appointment 19
buy picture hooks at hardware store 95
put house in listings at real estate office 75
buy tickets for basketball game at Ticketron 52
visit new show at art gallery 54
buy new record at one of the record stores 78, 22
look at stoves at appliance store and ONE
department store 57, 77, 12
visit neighbor in hospital 17
buy coffee mugs at Pier 1 58
buy tequila at liquor store 74, 92
buy candles at Truc 66
buy boots at leather goods store 99
restaurants 39, 31

Scenario 6

You have just finished working out at the health club. It's 11:00 and you can plan the rest of the day as you like, doing your errands in any order except for your last two which you will do on your way home. You need to pick up your car from the Maple Street parking garage by 5:30, and on your way home drop off clothes at the dry cleaners and fill up on gas. Then go home via Washington Avenue going east.

You will be going to see a movie. Show times at both movie theaters are the same: 1:00, 3:00, and 5:00. Both movies are on your list of "must see," but go to the one that most conveniently fits into the rest of your plan. Here's your errand list.

<u>Errand List</u>

health club 20
Maple Street garage 80
pick up medicine for dog at veterinary office 45
buy fan belt for refrigerator at appliance store 25
check out 2 of the 3 luxury apartments 73, 91, 89
meet friend at one of the restaurants for lunch 31, 39
buy toy for dog at pet store 28
see movie at one of the movie theaters 81, 70
pick up watch at watch repair 88
special order book at bookstore 86, 32, 14
buy fresh vegetables at grocery 9, 87
buy gardening magazine at newsstand 100
send flowers to friend in hospital at flower shop 24
* drop off clothes at dry cleaners 90, 101
* fill up on gas at gas station 72, 46, 5

* do these errands on the way home

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